LVM3

S200 BOOSTER

FIRST STATIC TEST

(S200-ST-01)

Vikram Sarabhai Space Centre
Thiruvananthapuram

Satish Dhawan Space Centre
SHAR, Sriharikota

January 24, 2010

S200, the largest solid rocket booster in Asia...

The LVM3 is configured with two strap-on boosters (S200), each carrying about 200 tons of HTPB based solid propellant. The vehicle takes off with the simultaneous ignition of both the boosters, which burn for about 130 seconds and separate at 149.3 seconds. The S200 is the third biggest solid booster of any launch vehicle in active service, after the solid rocket boosters of Space Shuttle and Ariane-5.

The maiden test of the S200 motor is scheduled to take place at the 6C test facility of Vehicle Assembly and Static Test Facilities (VAST) at Satish Dhawan Space Centre (SDSC) SHAR on January 24, 2010.

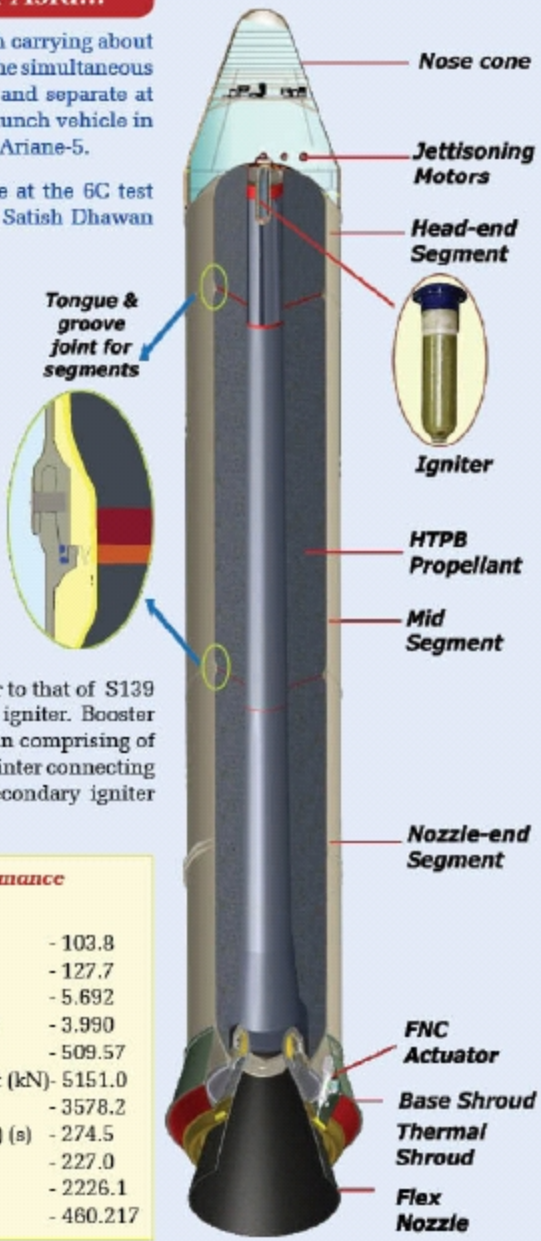
S200 Motor details

The S200 motor, which is formed of three segments, consists of four major components, viz., motor case, propellant, igniter, and flex nozzle with thrust vector control system.

The solid propellant, which is same as that of the PSLV/GSLV boosters, is HTPB based system with 86% of solid loading. While the head-end segment carries 27.1t of propellant, the nozzle–end and the middle segments are loaded with 82.21t and 97.38t respectively. All the three segments are produced at the world class Solid Propellant Plant (SPP), which was recently set up at SDSC SHAR with all the state-of-the-art facilities.

Igniter

The motor is ignited with a high caliber pyrogen igniter (similar to that of S139 motor), which in turn is set off by a secondary-add-on-pyrogen igniter. Booster charge of the secondary igniter is triggered through an ignition train comprising of two safe/arm units (for redundancy), explosive transfer assemblies, inter connecting manifolds, and through bulkhead initiators assembled to the secondary igniter head end. The igniter is realised and qualified by VSSC.



S200 Motor Specifications

• Overall length (m)	-	21.9
• Max. dia. (mm)	-	3200
• Skirt dia. (mm)	-	3270
• Propellant mass (t)	-	207
• Mass ratio	-	0.89
• Flex nozzle vectoring capability (in resultant plane)	-	±7.8°
• Number of segments	-	3
• Thrust time curve	-	M type
• FNC system	-	Electro-hydraulic system with blow down power pack

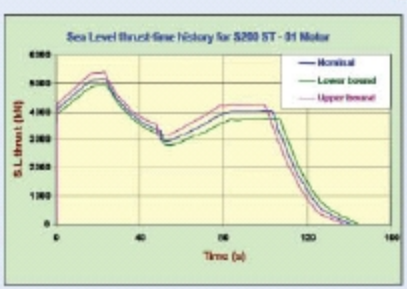
S200 Motor Performance (Nominal)

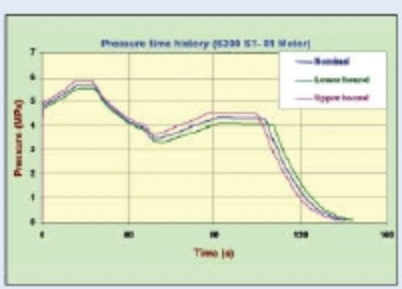
• Burn time (s)	- 103.8
• Action time (s)	- 127.7
• Max. pressure (MPa)	- 5.692
• Action time avg. Pr. (MPa)	- 3.990
• Pressure integral (MPa-s)	- 509.57
• Max. Sea Level (SL) thrust (kN)	- 5151.0
• Average SL thrust (kN)	- 3578.2
• Vac. Specific impulse (Isp) (s)	- 274.5
• SL Isp (s)	- 227.0
• SL Isp (N-s/kg)	- 2226.1
• Total SL. Isp (MN-s)	- 460.217

Propellant Properties

Parameter	Values
Mechanical	
Density (g/cc)	- 1.765 ± 0.005
Tensile strength (ksc)	- 7.0 (min)
Elongation at max. stress (%)	- 35 (min)
Initial modulus (ksc)	- 50±10
Hardness (Shore 'A')	- 70 ± 5
Interface Properties	
Tensile bond strength (ksc)	- 7.0(min) or Cohesive failure in the propellant
Peel strength (kg/cm)	- 0.6 (min.)

Predicted Performance

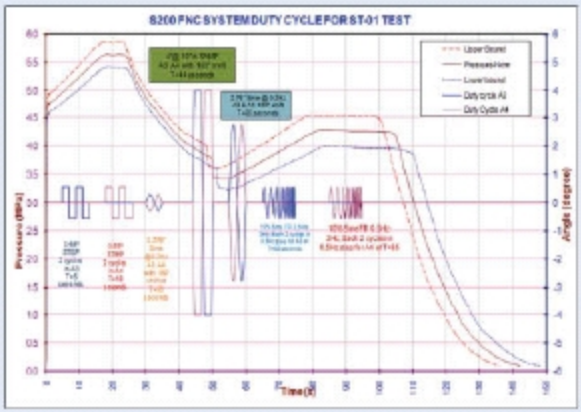




Flex Nozzle

The flex nozzle has contoured divergent with an area ratio of 12.1. Nozzle vectoring is achieved by electro-hydraulic servo actuators, with minimum 30t capability in pitch and yaw axes operated in blow down mode by stored Nitrogen gas and oil. The stage has a flared base shroud, which houses the actuation system and also supports the vehicle on mobile launch pedestal.

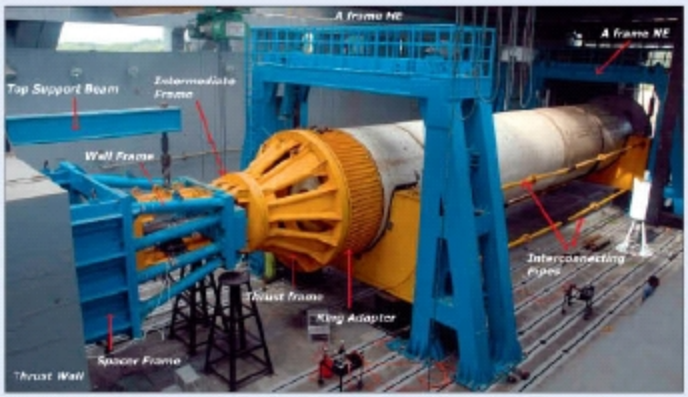
The flex nozzle with the thrust vector control system is developed, realised and qualified by S200 Project with the support from various divisions of VSSC & SDSC SHAR.



Objectives of static test

To evaluate the ballistic performance of the motor and motor case insulation system, and to qualify the hardware under motor operating environments.

- To evaluate the performance of the flex nozzle.
- To qualify the flex nozzle control system for the specified duty cycle.
- To evaluate ignition system performance.
- To demonstrate the adequacy of motor interfaces.
- To assess the slag accumulation in horizontal mode.
- To study the pressure & thrust oscillations, if any, during the operation of the motor.
- To demonstrate the performance of strap-on thermal boot and shroud under static test environment.
- To assess the acoustics level at various distances & orientation from nozzle exit.



S200 motor on static test bed

Test Stand & Measurement system

The special purpose six component (6C) test facility, which was originally set up for conducting the static tests on PS-1 booster (of PSLV and also GSLV) during 1980s, has been augmented to meet the static test requirements of S200 motor.

The refractory flooring of the test facility was extended for an area of 500 sq. m. The merlon was strengthened and extended. New motorised mobile shelters and sliding doors were provided. A sophisticated self propelled unit (SPU) of 400 t capacity was procured for transportation/ handling of motor/segments at SPP, Solid Stage Assembly Building (SSAB) and 6C Test Bed. The test stand has provision to measure the forces and moments along the three mutually perpendicular axes. It was qualified by mounting a dummy motor simulating the weight and dimensions of the S200 motor.

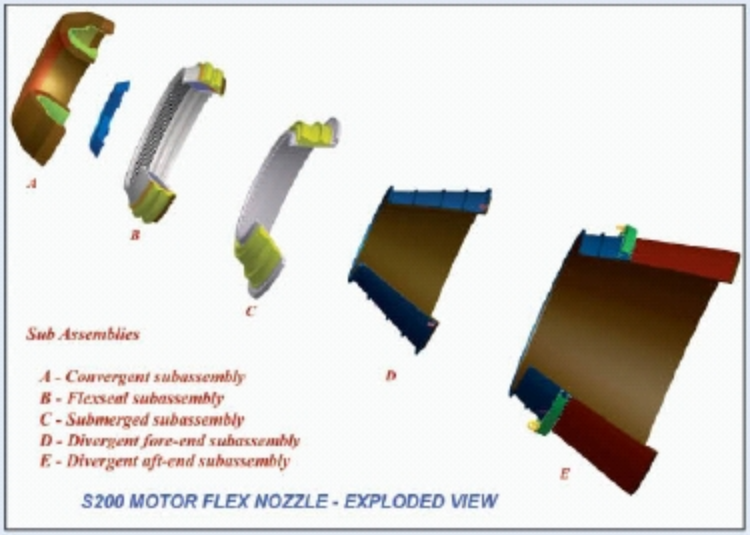
The calibration of the test stand system was carried out simulating the expected forces along axial, yaw and pitch directions. The instrumentation and measurement systems have been qualified by an exhaustive T & E programme. Closed Circuit Television and high speed movie cameras cover the total test.

Post Fire Extinguishing System

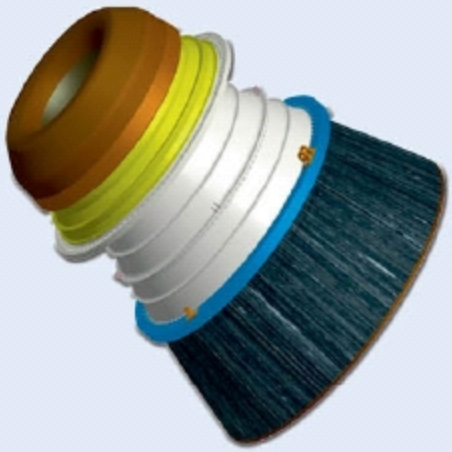
After the motor burn-out, the exposed insulation will continue to burn for some more time. Quenching this is essential for evaluating the erosion rate of insulation liner and thermal boot. 1000 kg of halon is injected into the motor through the nozzle-end for quenching the post-test burning. Subsequently, another 3600 lit. of water is also injected into the motor through a specially designed common injection system to cool the molten slag collected in the motor chamber. This prevents charring of the remaining insulation.

MEASUREMENT PLAN	Type	No. of channels
	Pressure	8
	Thrust	4
	Strain	233
	Temperature	194
	Displacement	10
	Vibration	18
	Acoustic	21
	High speed photography	12
	Pyro control	16
	Heat flux gauge	4
	Facility parameters	68
	FNC system parameters	66
	Total	*654*

FLEX NOZZLE



S200 MOTOR FLEX NOZZLE - EXPLODED VIEW



Specifications of Nozzle

Type: Submerged flex nozzle with contoured divergent. Consists of 5 subassemblies:

Throat Diameter (mm)	: 886
Area ratio	: 12.1
Submergence (%)	: 30
Overall Length (mm)	: 3474
Vectoring Capability	: ±7.8° (in resultant plane) ±5.5° (in actuation plane)
Flex Nozzle Torque at 5.50, kN-m (Kgf.m)	: 366.8 (37400)
Moment Arm (mm)	: 1500

Flex Nozzle Control System

Type : Dual plane Flex Nozzle Control, using 2 Nos. of Electro Hydraulic servo actuators (45° away from C -)

Vectoring capability in actuation plane	: ± 5.5°
Slew rate	: 10° /s
Moment arm	: 1.5m
Actuator Load capacity (min. at 205 bar)	: 294 KN
Actuator Stroke (total)	: 320 mm (+175.5/-144.5)
Power pack	: Hydro pneumatic piston type in blow down mode
Control Electronics	: Dual redundant with FDI logic

CONTRIBUTING AGENCIES

System	Agency
S200 Motor / Stage Design	: S200 Project, SMG, LVM3
Motor Case	: S200 Project, SMG, SATG, MME, QRMG, LVM3
Propellant System	: SMG, S200 Project, STAG, SPP, SPROB, QRG, RPP, PCM, QRPG, LVM3, APEP
Flex Nozzle	: S200 Project, SMG, STAG, PRG, CSTG, MME, QRMG, QRPG, ABSG, CCQG, CPSD, SPROB, QRPG, RPP, PCM
Flex Seal/Flex Nozzle System Testing	: PRG, S200 Project, CASG, MVIT, SR, SSCD/LPSC, LVM3, MME, SFD

System	Agency
Ignition System	: SOG, PRG, SMG, CSTG, CPSD, EFCA, QRPG, MME, QRMG
FNC System	: CASG, SATG, AVN, MME, SR, LVM3, SSCD/LPSC
Strap-on based Shroud	: SDE, S200 Project, LVM3, MME, QRMG
Strap-on Thermal Shroud	: LVM3, SATG, MME, SR
Strap-on Thermal Boot	: LVM3, AHTG, ABSG, QRPG
Trial-Actuation Test	: VAST, CASG, S200 Project, LVM3, SR, QRG, MVIT, LSSF, RO
Motor Assembly & Testing	: VAST, RO, SPP, QRG, AVN, SR, MVIT, PCM
Project Management	: S200 Project, LVM3

Production and assembly of S200 motor segments and subsystems

Motor case preparation at SPP

Propellant slurry transfer

Segment for propellant casting

Nozzle assembly

Segment assembly at SSAB/VAST

Tilting the assembled motor

Radiographic inspection of the assembled motor at SPP

Nozzle flex seal

Nozzle Assembly (Module -1)

Flex seal vectoring test

Nozzle integrated test

Nozzle trial actuation test

Designed and published by the Publicity & Publications Officer. Photos: Technical Photography Facility. Satish Dhawan Space Centre SHAR, Sriharikota-524124. January 2010

Operations on test stand at VAST / SDSC SHAR

Thrust frame being mated to the head-end of the motor

Checking the alignment

A view of the motor on the test bed